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(71) Applicant: **International Business Machines Corporation**
Armonk, N.Y. 10504 (US)

(72) Inventor: **Bauchot, Frédéric**
06640 Saint Jeannet (FR)

(74) Representative: **Schuffenecker, Thierry**
Compagnie IBM France,
Département de Propriété Intellectuelle
06610 La Gaude (FR)

(54) Medium access control scheme for a wireless access to an ATM network

(57) According to the present invention, an adaptive and efficient MAC protocol for wireless access to an ATM network (32) is capable of supporting any type of ATM service class with associated Quality of Services parameters. An ATM cell-switched architecture is utilised in which several ATM Mobile Terminals (10,12,14,16) within a given geographic cell (small cells covering a range of several tens of meters) communicate with an ATM Access Point (18,20) using radio frequency channels, which is connected to an infrastructure ATM network by the means of conventional ATM links. Mobile Terminals can operate both indoor and outdoor with limited range and have wireless access to the Access Points on the ATM network.

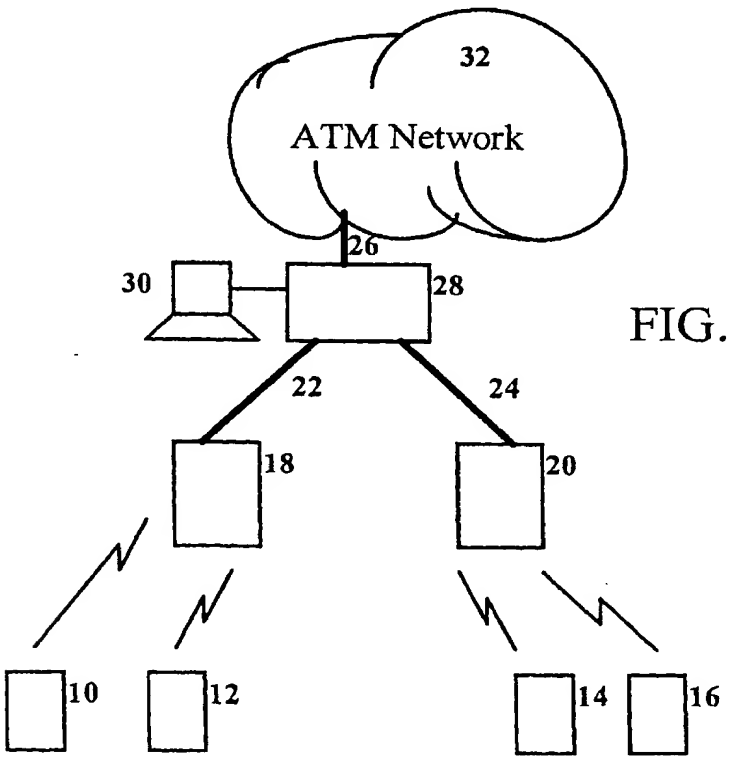


FIG. 1.

EP 0 804 006 A2

Description

Field of the Invention

The invention relates to data communication and particularly such communication combining the Asynchronous Transfer Mode (ATM) technology and the wireless transmission technology.

Specifically, the invention is directed to a Medium Access Control (MAC) protocol, including traffic scheduling policies.

Background of the Invention

Recently the ATM and wireless technologies have gained a high visibility as they provide efficient and economical answers to requirements raised by new telecommunication services and by new end-user behaviours.

ATM has been recognised as the common base on which different types of services and network can operate. The ATM technology can efficiently combine the transmission of speech, video, hi-fi sound (what is commonly called the multimedia traffic) and computer data into the wired network. Furthermore ATM has proven to scale well from very high speed network infrastructure (the information highways) to customer premises networks. One of the great advantage of the ATM technology is the fact that it can guarantee some level of service when an ATM connection is set up. Such guarantees can correspond to transmission rate, transmission latency and information loss. They can be achieved mainly because the ATM architecture assumes that the transmission media are almost error free.

Wireless technology is currently becoming more and more successful as it allows mobile end-users to remain connected to their network and applications while being freed from a wired attachment. Different approaches are currently proposed for wireless communications: they differentiate by the services and the coverage they provide. Wireless Wide Area Networks (WAN) like the so-called GSM provide nation-wide coverage to the end-user, with modem equivalent transmission speeds. Wireless Data Packet networks provide nation-wide coverage to the end-user, with the so-called X.25 like transmission services. Finally Wireless Local Area Networks (LAN) provide establishment wide coverage with conventional LAN (e.g. Ethernet) equivalent communication services.

The combination of Wireless transmission with ATM technology is a new trend whose objective is to take advantage of both technologies, and for example to allow a mobile user to access an ATM network infrastructure while taking full advantage of all the facilities available with a wired access to ATM network. Since the main characteristics of each technology are very different, even incompatible, such a combination raises technical problemes, as described hereinafter.

ATM technology characteristics

The ATM technology, as currently defined by standardisation bodies such as the ATM Forum, and as currently implemented by commercial products, is characterised by the following main aspects:

- Very short data granularity: in ATM network, all the traffic is carried within so-called ATM cells corresponding to a 53 bytes long structure made of a header field (5 bytes) and a payload field (48 data-bytes). The ATM cells are used either for control and signalling traffic or for information bearer traffic.
- Full duplex (FDX) links: on each ATM port, it is possible to simultaneously receive and transmit information.
- Point-to-point links: the media on which ATM cells are transmitted can only connect a pair of ATM stations. Although some ATM concentrator products can give the appearance of multidrop link, the ATM links have a point-to-point topology.
- Almost error free transmission: the transmission technologies currently used in ATM networks (e.g. over fibber or cable) provide typical bit error rate (BER) below 10-9. This capability is the main reason allowing to place the error recovery mechanisms within the ATM end stations and not within the ATM network.

On top of these aspects, the ATM architecture further introduces the concept of ATM Service Class traffic parameters and the one of Quality of Service (QoS) parameters to allow specifying, at ATM connection set-up, a traffic contract between the ATM end-point and the ATM network. These concepts aim to formalised by some means the characteristics of the user traffic so that each element of the ATM network involved in the end-to-end ATM connection may on one side reserve the necessary resources to provide the required service, and on the other side behave accordingly to the traffic contract. These concepts are summarised in the following table.

Table 1.

ATM Layer Services Categories						
Attribute	**CBR**	**rt-VBR**	**nrt-VBR**	**ABR**	**UBR**	**Parameter**
CLR	Specified	Specified	Specified	Specified	Unspecified	QoS
peak-to-peak CDV	Specified	Specified	Unspecified	Unspecified	Unspecified	QoS
Mean CTD	Unspecified	Unspecified	Specified	Unspecified	Unspecified	QoS
Max. CTD	Specified	Specified	Unspecified	Unspecified	Unspecified	QoS
PCR and CDVT	Specified	Specified	Specified	Specified	Specified	Traffic
SCR and BT	N/A	Specified	Specified	N/A	N/A	Traffic
MCR	N/A	N/A	N/A	Specified	N/A	Traffic
Flow Control	No	No	No	Yes	No	

CBR: Constant Bit Rate
rt-VBR: real time Variable Bit Rate
nrt-VBR: non real time Variable Bit Rate
ABR: Available Bit Rate
UBR: Unspecified Bit Rate
CLR: Cell Loss Rate
CDV: Cell Delay Variation
CTD: Cell Transfer Delay
PCR: Peak Cell Rate
CDVT: Cell Delay Variation Tolerance
SCR: Sustainable Cell Rate
BT: Burst Tolerance
MCR: Minimum Cell Rate
N/A: Not applicable

Finally, the channel should at least provide a capacity of 20 to 25 Mbps, in order to meet the throughput requirements of expected ATM applications.

The IBM Publication GG24-43300-00 titled 'Asynchronous Transfer Mode, Technical Overview' presents a broad overview of the ATM concept and details the ATM technology characteristics.

Wireless technology characteristics

The wireless transmissions are characterised by the following main aspects:

- Poor efficiency to transmit short packets: before transmission of any piece of data over a radio channel, the transmitter must first issue a so-called Physical header which typically correspond to a significant portion of the bandwidth. In order to decrease the associated overhead, the piece of data which is transmitted next must be sufficiently large. For instance with conventional WLAN products, a frame of 1500 bytes (or more) follows the physical header.
- Half Duplex (HDX) links: the only way to allow FDX operation over a radio channel is first to duplicate the radio modem transceiver (one part dedicated to transmission, the other to reception), and second to split by some means the frequency band into two sub- bands, each of them being used for a one-way transmission. Such an approach is quite expensive and also raises some technical difficulties such as the saturation of the receiving antenna by the emitting one. As a result the only technically and economically viable approach is to rely on a single radio transceiver piece of hardware, and to use the radio channel in HDX mode.
- Broadcast transmission: the nature of the electromagnetic waves transmission is such that any receiver within range of a transmitter beam can get enough energy to receive information sent by the transmitter. Thus the wireless channel topology must be seen as point-to-multipoint. The use of directional antennas may reduce the reception area and thus the population of potential receivers, but it prevents any mobility of wireless stations. This last limitation is unacceptable for a wireless ATM network aimed to provide mobility support to mobile end-users. As a result, the wireless radio channel must be seen as a multidrop link.

- High error rate: wireless transmission channels are characterised by poor quality figures. Typically the bit error rates observed on such wireless channels may be as bad as 10-3 or 10-4: they are by far higher than what is assumed by ATM networks.

The 'Mobile Communications HandBook' by Jerry D.Gibson, CRC IEEE Press, 1996, ISBN 0-8493-8573-3, gives an extensive description of the wireless technology.

From the aforementioned points, it clearly appears that the wireless and ATM technologies significantly differ on important transmission characteristics which are resumed hereafter:

- The ATM cells are so short that they would induce poor transmission efficiency if they were sent individually over the radio channel, as it is performed over conventional ATM transmission media. Radio transmissions cannot economically provide Full Duplex transmissions which are commonly used on ATM networks.
- The topology of radio transmissions are not equivalent to the ones found in ATM networks.
- The bit error rates observed over radio channels are by far worse that the ones assumed by the ATM architecture.

Some known techniques intend to address the technical challenges previously introduced, and may fill the gap between the wireless and the ATM technologies.

A first solution based on high speed point-to-point radio links may meet the requirements of a Wireless ATM network in term of channel capacity, but cannot provide a satisfying answer to other needs. The main limitation is the point-to-point topology preventing wireless end-user to be mobile. In addition, the scheduling policies commonly used on such radio links have not been built to meet the QoS requirements of ATM connections.

Others solutions based on the conventional WLAN techniques are to some extend in line with some requirements of a wireless access to an ATM network, but cannot address all of them. As far as the channel capacity is concerned, some techniques, as the one developed by the ETSI RES10 committee (the so-called HIPERLAN standard) provide a throughput which may be sufficient for some ATM scenarios. Concerning the channel topology and usage (FDX vs HDX), the patent US-A 5,384,777 to Ahmadi et al provides some techniques for defining a Wireless ATM network, but this solution suffers from important limitations. The most important one is the fact that the used traffic scheduling policy gives a solution to the support of conventional LAN traffic, but cannot guarantee at all the QoS requirements imposed by any type of ATM traffic. In addition to this limitation, the design point of traditional wireless LAN products is optimised for conventional LAN traffic (based on large packets: 1.5 Kbytes or more) and therefore presents very poor efficiency figures if packets are replaced by ATM cells.

Therefore, it appears that the conventional wireless LAN technology does not fulfil the requirements of a wireless access to an ATM network.

Accordingly, it would be desirable to be able to provide a method capable of supporting any type of ATM service class with associated QoS parameters in a communication system providing a wireless access to an ATM network.

Furthermore, it would be desirable to be able to provide a system coordinating and optimizing the wireless channel bandwidth which is shared by all Mobile Terminals within a cell in a fair, flexible and ATM compatible manner and to achieve a high throughput.

Summary of the Invention

A MAC protocol for wireless Radio Frequency (RF) or Infra-Red (IR) access for a plurality of ATM Mobile Terminals to an ATM Access Point is disclosed. The MAC protocol is based on a reservation scheme for the portion of the user traffic which is guaranteed by the ATM contract during the ATM connection set-up, and a random access technique for the portion of the user traffic above the guaranteed level, and for the MAC control traffic. There is a time division structure in which time is slotted, and time slots are grouped into variable length time frames consisting of downlink time slots and uplink time slots. The variable length time frame consists of three periods (DOWN, UP_RESERVED, UP_CONTENTION). The first period, the DOWN period, is the downlink channel which is used exclusively for data transfer from the Access Point to the Mobile Terminals. The following period, the UP_RESERVED period, is the uplink channel that is used for contention-free data transfer from the Mobile Terminals to the Access Point. The allocation of the time slots in the DOWN and UP_RESERVED periods is performed by the Access Point, and depends on one side on the service class and QoS parameters of each established ATM connection between the Mobile Terminals and any ATM station according to different priority levels derived from the ATM contract parameters, and on the other side the allocation of the time slots depends on the instantaneous traffic characteristics of these ATM connections. The portion of the uplink bandwith which is reserved by the Access Point to a given Mobile Terminal is used by this Mobile Terminal to send traffic according to ATM class and QoS parameters. The last period of the frame, the UP_CONTENTION period, is the uplink channel used by the Mobile Terminals to transmit reservation requests, or data packets or control packets in a random-access contention mode using the slotted Aloha technique. For instance the close to expiry ATM cells will

be sent within the UP-CONTENTION period if they cannot wait for a next frame slot reservation. The duration of theses three periods, as well as the duration of the complete time frame made by these three periods may be varied using a movable boundary technique within the limits of upper bounds whose values also depend on the ATM class and QoS parameters of active connections. The traffic is scheduled by the Access Point which specifies at the beginning of each time frame in a dedicated control packet called the Frame Header, how each time slot of the time frame is allocated.

More generally, the invention relates to a method and an apparatus for a medium access control (MAC) scheme in a data communication system of the type comprising at least one first network based on a first technology, and including at least one station, at least one second network based on a second technology, and including at least one station, and wherein the first and second network technologies being of a different type, the system also comprising access means for providing communication between the stations of the first and the second networks, the method of the invention including the steps of defining a plurality of successive time frames during which traffic of data from the first or the second technology is carried out, and scheduling the exchange of data information during each successive time frame according to network parameters of each first and second networks, and according to traffic characteristics and constraints.

Brief Description of the Drawings

- FIG. 1 is a pictorial diagram showing a communication system providing wireless access to an ATM network of the type in which the invention is implemented.
- FIG. 1A is a block diagram of the system shown in FIG. 1 illustrating the basic components of a Mobile Terminal and an Access Point.
- FIG. 2 is a block diagram of the radio system used in the implementation of a preferred embodiment of the invention.
- FIG. 3 is a diagram of the structure of the MAC protocol time frame according to the invention.
- FIG. 4 is a block diagram of the Access Point MAC entities used in the implementation of a preferred embodiment of the invention.
- FIG. 5 is a flow chart of the logic followed by the Access Point Master Scheduler according to the MAC protocol of the invention.
- FIG. 6 is a block diagram of the Mobile Terminal MAC entities used in the implementation of a preferred embodiment of the invention.
- FIG. 7 is a flow chart of the logic followed by the Mobile Terminal Slave Scheduler according to the MAC protocol of the invention.

Description of the Preferred Embodiment

A MAC protocol is described that is based on an hybrid scheme relying both on reservation and contention techniques. The traffic supported by this protocol encompasses on one side any ATM traffic (including ATM bearer information and ATM signalling information), and on the other side some control traffic needed for the operation of the MAC protocol. The proposed scheme is based on a time division frame structure whose length is variable. Time is slotted, and time slots are grouped into time frames. The time frame is also divided into three periods: the DOWN period, is the downlink channel which is used exclusively for data transfer from the Access Point to the Mobile Terminals, the following period, the UP_RESERVED period, is the uplink channel that is used for contention-free data transfer from the Mobile Terminals to the Access Point, and the last period of the frame, the UP_CONTENTION period, is the uplink channel used by the Mobile Terminals to transmit reservation requests, or data packets or control packets in a random-access contention mode using the so-called slotted Aloha technique.

From Table 1, it appears that very different traffic classes are today part of the ATM architecture and that they require different kinds of support. It means that the Access Point, when scheduling traffic between all the alive ATM connections, must be aware of the traffic and QoS parameters in order to guarantee the traffic contract. This guarantee can only be delivered if some deterministic method (as opposed to contention-based method) is used for allocating bandwidth to each individual ATM connection. This is the justification of using a reservation technique. In the later, the entity of the Access Point which is in charge of scheduling the traffic will be referred to as the Scheduler. More accurately, this entity is called the Master Scheduler, as opposed to the Slave Scheduler which is the Mobile Terminal entity in charge of assigning ATM cells to the uplink time slots reserved by the Access Point to the Mobile Terminal, and of generating the bandwidth reservation requests. Then, the invention includes the following features:

- A reservation method which is based both on ATM connection service parameters and on instantaneous traffic load information.
- A unified scheduling policy for support of any type of ATM traffic and of control traffic.
- A queuing and memory management method minimising the data movements needed before real transmission of

ATM cells be performed.

- A technique for flexibly and dynamically adjusting the time frame boundaries and lengths to achieve maximum throughput and to guarantee ATM service class and QoS parameters.

Referring now to the drawings, and more particularly to FIG. 1, there is shown a wireless network allowing communication between a plurality of Mobile Terminals (10, 12, 14, 16) and applications hosted by ATM stations (not shown) belonging to the ATM network 32. The computing system includes an ATM Switch 28 or equivalent equipment, with attached monitor station 30, which is connected to the ATM network through a conventional ATM link 26, and to one or more Access Points (18, 20) through conventional ATM links (22, 24). These Access Points are featured according to the invention with radio system management functions which coordinate the Mobile Terminals access to the shared radio channel.

As shown in more details in FIG. 1A, an Access Point 18 or 20, which may be a conventional ATM concentrator or a microcomputer, has an ATM adapter 34 inserted in a bus slot and connected to the ATM link 22 or 24. The ATM switch 28 also has an ATM adapter 36 inserted in a bus slot and connected to the ATM link 22 or 24. The ATM link 22 or 24 is of conventional design and does not form part of the invention. The Access Point 18 or 20 also has a RF transceiver adapter 38 implemented as a printed circuit card which is inserted in a bus slot of the Access Point. The transceiver adapter 38 has an antenna 40 by which a radio link 42 is established with one or more Mobile Terminals (10, 12, 14, 16). The Mobile Terminal may itself be any type of conventional design computer and, like the Access Point, it is provided with a transceiver adapter 46, also implemented as a printed circuit card which is inserted in a bus slot of the computer, and an antenna 44. The Access Points and the Mobile Terminals are further provided with software (48, 50) which supports their respective transceiver adapters.

Now referring to FIG. 2, the radio system common to both the Mobile Terminals and the Access Points of FIG. 1, is shown. The radio system includes a transceiver adapter 38 or 46 connected to the computer 52 via the computer bus interface 54. The transceiver section is itself divided into an RF transceiver 56, which may be a commercially available 'GMSK' or 'OFDM' based transceiver, and a dedicated microprocessor system 58 which controls the transceiver via an interface 60. The microprocessor system 58 further includes a system interface 62 which interfaces the transceiver section to the computer section 52. The microprocessor system includes a dedicated microprocessor 64 running real-time oriented operating system and including some high-resolution hardware timers. Microprocessor 64 is connected by a memory bus 66 to program storage 68 and data storage 70 as well as to interfaces 60 and 62 providing attachment to bus interface 54 and RF transceiver 56, respectively. Program storage 68 is typically read only memory (ROM), while data storage 70 is static or dynamic random access memory (SRAM or DRAM). Packets received or to be sent are held in data storage 70 and communicated to or from the RF transceiver 56 via interface 60 under control of serial or parallel channels and a direct memory access (DMA) controller which is part of the microprocessor 64.

The computer 52 runs an operating system 72 which supports one or more user application programs 74. The operating system 72 may include an ATM compatible communications manager 76, or the ATM compatible communications manager 76 may itself be an application program installed on the computer. In either case, the ATM compatible communication manager 76 controls a device driver 78 via the operating system 72. The device driver 78, in turn, communicates with the transceiver adapter 38 or 46 via bus interface 54.

The protocol system is now described, and particularly the time frame structure is detailed with reference to FIG. 3.

Time Frame Structure

The variable length frame structure consists in three periods (DOWN, UP_RESERVED and UP_CONTENTION), as shown in FIG. 3, and of a Frame Header (FH) control packet belonging to the DOWN period. The DOWN period is the downlink channel which is used exclusively for data transfer from the Access Point to the Mobile Terminals. The UP_RESERVED period is the uplink channel that is used for contention-free data transfer from the Mobile Terminals to the Access Point. The UP_CONTENTION period is the uplink channel used by the Mobile Terminals to transmit reservation requests, or data packets or control packets in a random-access contention mode using the slotted Aloha technique.

The protocol is driven by the Master Scheduler entity running in the Access Point, in charge of scheduling all the traffic originating in the different sources of the wireless cell. The output of the Master Scheduler is a slot map which is carried in the FH packet broadcast at the beginning of each time frame. This slot map specifies several information concerning the current time frame. First it indicates the length of the time frame, second where are located the boundaries between the DOWN and UP_RESERVED periods on one side and between the UP_RESERVED and UP_CONTENTION periods on the other side, and finally how the bandwidth available in the time frame is allocated to the different sources active in the wireless cell. By receiving the slot map carried in each FH packet, each individual Mobile Terminal can learn on the fly the characteristics of the current time frame and also when it is authorised to either send or receive a given packet over the wireless channel.

Each of the tree periods introduced above is further split into a finite (and upper bounded) number of time slots, which are the time granularity used to specify bandwidth allocation. As it will be outlined later, a specific aspect of the invention is the fact that contiguous transmission can be spread over consecutive time slots, increasing therefore the overall efficiency of the protocol. This aspect is quite different from other conventional Time Division Multiple Access (TDMA) schemes (such as the ones used in conventional wireless LAN), where every time slot contains the transmission of a single piece of information, including therefore the overhead introduced by the RF transceiver for synchronisation or equaliser convergence purpose.

Traffic Priorities

When the Master Scheduler allocates time slots to the various ATM connections alive in the wireless cell, it must take into account the respective characteristics of each of them in order to guarantee the service class and QoS parameters which have been set-up when the ATM connections were established.

In order to minimise the computing overhead of the Master Scheduler, it is possible for any type of ATM service class to identify some consistent behaviour of the Master Scheduler. The invention proposes to define for each ATM service class two different thresholds: the Reserved Bandwidth (RBW) threshold and the Peak Bandwidth (PBW) threshold. These thresholds can be easily mapped to ATM service class parameters, as outlined in the following table.

Table 2.

RBW and PBW thresholds					
ATM Services Class	**CBR**	**rt-VBR**	**nrt-VBR**	**ABR**	**UBR**
RBW	PCR	SCR	SCR	MCR	N/A
PBW	PCR	PCR	PCR	PCR	PCR

Some conventional techniques, like leaky bucket algorithms, can be used either in the Access Point or in the Mobile Terminal, to determine for each ATM cell to be transmitted over the wireless channel, if it corresponds to traffic either above or below the two former thresholds.

The scheduling policy is based on these two thresholds.

The portion of the traffic which remains below the RBW threshold is carried out in time slots which are statically reserved when the ATM connection is set-up. It means first that the Master Scheduler must be aware of the traffic characteristics when any ATM connection is set-up, and second that the Master Scheduler allocates on a regular basis the necessary number of time slots required to reach the RBW traffic threshold. Different techniques can be applied to ensure that the Master Scheduler be aware of the ATM connection traffic characteristics. They are not part of the present invention and can rely for instance on some dedicated control protocols between the Access Point and the ATM Switch (28 in FIG. 1), or on some spying of the ATM signalling flow passing through the Access Point when the ATM connection is set up.

The portion of the traffic which remains between the RBW and the PBW thresholds is carried in time slots which are either dynamically reserved or (for the uplink traffic) sent in the UP_CONTENTION period, at the time this traffic arises. It leads to introduce some means allowing the Mobile Terminals to inform the Access Point when such uplink traffic occurs between the RBW and the PBW thresholds. Such means correspond to a bandwidth request channel that carries time slot reservation requests from the Mobile Terminals to the Access Point. Such request can be carried either as piggybacked information in packet flowing during the UP_RESERVED period, if any, or to some dedicated control packet sent in the UP_CONTENTION period. In both cases the request should specify the required number of time slots to be allocated as well as some identifier of the corresponding ATM connection. Alternatively, it is also possible for the Mobile Terminal to issue in the UP_CONTENTION period a data packet with piggybacked information corresponding to the remaining packets not yet transmitted.

Finally, the portion of the traffic which sits above the PBW threshold can be handled in a similar way to the one located between the two thresholds, but the Master Scheduler must be able to distinguish them. Indeed as outlined later, the priority assigned by the Master Scheduler to these two types of traffic (either above or below the PBW threshold) will differ and the corresponding ATM cells may be tagged with Cell Loss Priority (CLP) bit set to the value 1.

Therefore, it is possible, thanks to the bandwidth request channel, to let the Access Point be aware of any uplink traffic above the PBW threshold. As far as the downlink traffic is concerned, the Access Point can determine alone which portion of the traffic sits above or below the RBW or PBW thresholds. The combination of these two information gives to the Master Scheduler a comprehensive view of all the outstanding traffic, which can be split on one side between the uplink traffic and the downlink traffic, and on the other side according to their position with respect to the RBW and PBW thresholds.

The Master Scheduler operates by defining some priorities to the different types of traffic identified above. The first criteria to assign priorities is derived from the service guarantee that the ATM connection has received at connection set-up. It means that the traffic sitting before the RBW threshold must be served first, then the traffic located between the RBW and PBW thresholds must be served second and finally the remaining traffic sitting above the PBW threshold must be served last. As Call Admission Control is used in ATM networks, there should be no difficulty to serve all the traffic sitting below the RBW threshold. It means that the channel capacity should always absorb all the possible ATM traffic as long as it does not exceeds its RBW threshold. The second criteria to assign priorities is related to the ATM service class, because some service classes are more time sensitive than others. The conventional priority to be used here is to give the highest priority to the more time sensitive traffic, so that it corresponds to the following order (by declining priorities): CBR, rt-VBR, nrt-VBR, ABR and UBR. Finally it should be also decided how the uplink traffic is served vs the downlink traffic. The expected networking environment that can be anticipated for wireless access to ATM network is such that the Mobile Terminals will most of the time host some client applications interoperating with server applications running in the ATM infrastructure network. The resulting traffic will be unbalanced between the uplink and the downlink path, most of the traffic being carried out along the downlink path.

The following table (Table 3) specifies for all the different traffic types the associated priorities assigned by the Master Scheduler (the higher priority corresponding to the lower index 1).

Table 3.

Priority by Traffic Type				
	Traffic type	**Below RBW**	**RBW to PBW**	**Above PBW**
CBR	down	1	N/A	17
CBR	up	2	N/A	18
rt-VBR	down	3	9	19
rt-VBR	up	4	10	20
nrt-VBR	down	5	11	21
nrt-VBR	up	6	12	22
ABR	down	7	13	23
ABR	up	8	14	24
UBR	down	N/A	15	25
UBR	up	N/A	16	26

Cell Train Concept

Having set the priorities for each traffic type, it is necessary to arrange the transmission of the corresponding ATM cells in a way maximising the overall protocol efficiency. As wireless transmissions suffer on one side from an important overhead introduced by the RF transceiver, and on the other side from a low quality bit error rate, some innovative means must be introduced. In conventional wireless LAN techniques, the frames to be carried over the wireless channel are typically large so that they may require some segmentation before being transmitted. The segment size is chosen as a good balance between a too large size inducing bad Block Error Rate figures and a too small size inducing bad protocol efficiency figures. With ATM traffic, the problem is quite different as the information granularity (the ATM cell) is very short, compared to regular MAC frames found in LAN networking environments. Thus it is necessary to introduce some grouping of the ATM cells, resulting in a so-called cell train . Such cell trains correspond to a contiguous data stream made of the concatenation of successive ATM cells. As such cell train may contain a variable number of ATM cells, it would not be efficient to map the slot size on the maximal cell train size. Then it is proposed in the invention to define the slot size as being equal to the time duration required to transmit a single ATM cell so that any cell train will only consume the minimal number of time slots required for its transmission. Such cell trains correspond to the piece of information carried over the wireless channel between peer wireless MAC entities and can thus be matched to the so-called MAC Protocol Data Unit (MPDU), as commonly used in the OSI model. A cell train can be constituted by a single ATM cell, or by several of them, but constraints imposed by the characteristics of the RF transceiver (for instance for clock recovery purpose) ask to upper bound their number. We will denote by Ntrain the maximal number of ATM cells per cell train or MPDU. These cell trains will be transmitted in the different periods of the time frame, according to the scheduling policy specified by the Master Scheduler.

Time Frame Length

The length of the time frame must be set as the optimum trade-off between a too short duration (inducing excessive overhead due to the FH packet) and a too long duration (inducing excessive latency, mainly for the real-time traffic). These two constraints may evolve over the time as a result of varying characteristics of the traffic, both in terms of traffic volume and in terms of traffic nature. As a result a variable length time frame can ensure optimisation of the protocol efficiency in terms of both throughput and quality of service.

If the volume of traffic is quite low (meaning that the channel capacity is much larger than the amount of traffic), there is no penalty of using short time frames inducing a lot of transmitted FH packets. If the traffic is not time critical, there is no penalty of using long time frames inducing a relatively large latency to go through the MAC layer. In the general case, the Master Scheduler must determine the maximal time frame length on the base of the service class and QoS parameters of the various ATM connections currently carried over the wireless channel. This upper bound, expressed in time slots, is represented by the variable NTF_MAX. It is computed by a dedicated algorithm (run by the Master Scheduler) which uses the service class and QoS parameters of the ATM connection quantifying to which limits successive ATM cells can be grouped together (and thus be delayed). In the preferred embodiment of the invention, the parameters PCR, CDVT, CTD and BT (as defined in Table 1) are used to derive NTF_MAX. The time interval TCELL (evaluated in time slot duration units) between two successive ATM cells, is directly derived from the PCR parameter, and the number CGROUP of ATM cells that can be grouped together, is directly derived from the parameters CDVT, CTD and BT. From these two parameters TCELL and CGROUP, the maximum time frame duration NTF_MAX is computed with respect to the following equation:

Equation 1: Time frame maximum size evaluation

$$NTF_MAX = \text{Min. of all Connections } (a \times TCELL \times CGROUP + b, c),$$

where the coefficients a, b and c allows to take into account some implementation constraints, such as available memory size or microprocessor computing power.

Another constraint to be taken into account is the fact that the UP_CONTENTION period cannot be empty as the traffic occurring during it cannot be anticipated by the Master Scheduler. It is not the case for the two other periods (with reserved traffic) as the Master Scheduler knows exactly which amount of traffic is reserved (this traffic being possibly null). Thus in each time frame, the Master Scheduler must allocate a minimum number of time slots for the UP_CONTENTION period. In addition, the length of this period must also evolve over the time as evolves the number of Mobile Terminals (to avoid situations where a too large population of Mobile Terminals contend on a too small number of contention time slots). The Master Scheduler estimates it as the sum of two parameters: NUP_CONTENTION = N1 + N2. The first parameter N1 is constant and corresponds to the minimal number of contention-based time slots needed to allow any new Mobile Terminal to signal its presence to the Access Point. Indeed when a brand new Mobile Terminal wishes to enter a wireless ATM network, it is unknown from the Access Point so that it can only rely on contention-based time slots to issue the very first control packet notifying the Access Point of its presence. The second parameter N2 corresponds to the time slots needed by the Mobile Terminals known by the Access Point to place reservation requests. As such reservation requests can be carried either as information piggybacked within uplink MPDU (during the UP_RESERVED period), or as a dedicated control packet issued during the UP_CONTENTION period, the Master Scheduler computes N2 from the number of known Mobile Terminals for which uplink traffic is not scheduled during the current time frame. If this number is represented by MTUP_IDLE, then N2 is estimated as a function of MTUP_IDLE, such that N2 = f(MTUP_IDLE), where the function f(x) can be a linear or an exponential function of x. The exact definition of f(x) is dependent on some implementation constraints, such as the computational capabilities and the computing power available in the implemented microprocessor. Nevertheless, f(x) must increase when x increases.

Finally, if the number of time slots found in the time frame, in the DOWN period and in the UP_RESERVED period are respectively represented by the variables NTF, NDOWN, and NUP_RESERVED, then the Master Scheduler must perform its slot allocation process under the following constraint:

Equation 2: Time frame upper limit

$$NTF = NDOWN + NUP_RESERVED + NUP_CONTENTION,$$

wherein NTF = < NTF MAX.

The operation at the Access Point is now described with reference to FIG. 4. The process run by the Access Point

can be split into three different tasks: the first task run by an ATM cell Handler, referenced as 80, which interacts with the interface 62, either sends or receives ATM cells from the upper layer component; the second task is run by an MPDU Handler, referenced as 82, which interacts with the interface 60 to either send or receive MPDU from the RF transceiver; and the third task is run by the Master Scheduler, referenced as 84.

The ATM cell Handler 80 and the MPDU Handler 82 interface themselves by the means of two different queues: the transmission queue, or XMIT_Q referenced as 86, and the reception queue, or RCV_Q referenced as 88. Further a reservation request queue RES_Q referenced as 90 is used between the MPDU Handler and the Master Scheduler to log any received reservation request previously issued by a Mobile Terminal.

ATM Cell Handler at the Access Point

The ATM cell Handler 80 is further split into two sub-entities: one dealing with reception of ATM cells from the interface 62 (left side of block 80 on FIG. 4), the other sub-entity dealing with transmission of ATM cells to the interface 62 (right side of block 80 on FIG.4).

The reception side is responsible for building the so-called cell trains on the base of the successive ATM cells received from interface 62. Then in a preferred embodiment of the invention, a dedicated memory management scheme is used where the available memory (within data storage 70) is organised as a pool of buffers, each buffer being dimensioned to contain a train made of Ntrain x ATM cells. At any point in time, several such buffers are available, each of them corresponding to a given traffic type, as identified in Table 3 (down link traffic corresponding to the odd index). The selection of the right buffer to use is based on the suggested leaky-bucket algorithm which can specify for any incoming ATM cell the associated priority, based on the corresponding service class and the position with respect to the thresholds RBW and PBW. If the buffer is found full (meaning that the received ATM cell is the last one of the cell train), then a new buffer must be dynamically allocated to host other ATM cells to come later. As each buffer is associated to a unique traffic type, it means that the XMIT_Q queue is implicitly instanced by traffic types. It can thus be seen as a set of different sub-queues MPDU_Qj, each of them being characterised by its own priority index j (odd index), as specified in Table 3.

The transmission side of the ATM cell Handler, is responsible for transmitting to the interface 62 the different ATM cells which have been previously received within MPDU from the interface 60. When an ATM cell has been passed to the interface 62, the corresponding memory can be returned to a pull of free memory.

MPDU Handler at the Access Point

The MPDU Handler 82 is further split into two sub-entities: one dealing with reception of MPDU from the interface 60 (right side of block 82 on FIG.4), the other sub-entity dealing with transmission of MPDU to the interface 60 (left side of block 82 on FIG.4).

The transmission side is responsible for sending to the interface 60 the MPDU specified in the slot map built by the Master Scheduler 84 during the DOWN period. Once a MPDU transmission is complete, the associated buffer can be released and returned to a pool of free buffers.

The reception side is responsible for receiving from the interface 60 the MPDU specified in the slot map built by the Master Scheduler 84 during the UP_RESERVED period, and also those received during the UP_CONTENTION period. For each received MPDU, the reception side has several tasks to perform. First it must extract the ATM cells from the MPDU and enqueue them in the RCV_Q queue. Second it must identify any reservation request carried in the received MPDU and pass it to the Master Scheduler through the RES Q queue referenced as 90.

Master Scheduler

The Master Scheduler 84 operates each time a time frame ends. At this instant, its task is to schedule the traffic for the next time frame to come, based on two information: the amount and nature of the waiting downlink and uplink traffic, as represented by the content of both the XMIT_Q queue 86 (more precisely the sub-queues MPDU_Qj) and the reservation request queue RES_Q 90, and the second information is the characteristics of the various ATM connections flowing over the wireless channel, referenced as 92. The same way the XMIT_Q has been split into sub-queues MPDU_Qj (the index j being odd), it is also possible for the uplink traffic to define sub-queues MPDU Qj (the index j being even). This task is performed by the Master Scheduler from the information 92 and from the RES Q 90. The ATM connection parameters specify the part of the traffic which will be statically reserved by the Master Scheduler (indexes 2, 4, 6 and 8 in Table 3): they allow to build the sub-queues MPDU Qj, where j takes the values 2, 4, 6 and 8. Note that any uplink MPDU or cell train cannot be shared between different Mobile Terminals. Nevertheless they can contain ATM cells belonging to different ATM connections as long as these connections originate in the same Mobile Terminal. The reservation requests logged in RES_Q, combined with the RBW and PBW thresholds, as derived

from parameters 92, dictate the content of the remaining uplink sub- queues MPDU_Qj, where j takes the even values between 10 and 26 included. Here again the same constraint concerning the sharing of a given uplink MPDU between different Mobile Terminals applies. When the Master Scheduler has performed this task, it can then go through all the MPDU_Qi where the index j varies within its full range, and allocate accordingly the traffic under the constraint of Equation 2.

Before further describing the Master Scheduler process, let introduce the following notations:

- The MPDU_Qi contains a number of MPDU equal to Mi. Each of them is noted MPDUi,j and contains ci,j ATM cells (the index j varies between 1 and Mi). The aggregate number of ATM cells in MPDU_Qi is equal to ci.
- The FH control packet issued at the beginning of each time frame is carried in a dedicated MPDU called FH_MPDU, which is enqueued in a specific queue MPDU_Q0 of highest priority. This MPDU contains nFH ATM cells.
- Each time any MPDU is sent over the air, the corresponding overhead of the RF transceiver consumes nRF equivalent ATM cells.

The Master Scheduler processing is represented by FIG. 5. At the very beginning, the Master Scheduler initialises the static variables nFH and nRF (block 104). Then it enters an endless loop which occurs each time a time frame completes (block 120). The first task in this loop is to evaluate, based on the algorithms previously described, the upper bound of the current time frame NTF_MAX from the information 92 specifying the parameters of the current ATM connections flowing over the wireless channel, as well as the duration of the third UP_CONTENTION period represented by the variable NUP_CONTENTION (block 106). Then the Master Scheduler evaluates the variables ci,j from the content of the uplink MPDU_Qi queues, first with index i less than or equal to 8 (block 108), then with index i taking the remaining values (block 110). Then the Master Scheduler initialises the current time frame (block 112) by filling it with the FH_MPDU (which is always present, even if no traffic is scheduled at all), and by initialising the time frame length n with the number of time slots required to transmit FH_MPDU. At this point, the Master Scheduler enters another loop, for each of the queue MPDU_Qi, and for each MPDUi,j within this queue to update the slot map of the current time frame. This construction is done in block 114 as long as the aggregate total number of time slots belonging to the two first periods DOWN and UP RESERVED remains below the upper limit NTF_MAX - NUP_CONTENTION. If this upper limit is reached or if all the reserved traffic can be scheduled, the Master Scheduler completes the slot map by adding the last period UP_CONTENTION to the current time frame (block 116). Finally the slot map is recorded in the FH_MPDU which is enqueued in MPDU_Q0, and the main loop completes when the Master Scheduler provides the MPDU Handler with the slot map to be used to initiate either MPDU transmissions or receptions during the current time frame (block 118).

The operation at the Mobile Terminal is now described with reference to FIG. 6. The process run by the Mobile Terminal can be split into three different tasks: the first task is run by an ATM cell Handler, referenced as 94, which interacts with the interface 62 to either send or receive ATM cells from the upper layer component; the second task is run by an MPDU Handler, referenced as 96, which interacts with the interface 60 to either send or receive MPDU from the RF transceiver; and the third task is run by the Slave Scheduler, referenced as 98. The ATM cell Handler and the MPDU Handler interface themselves by the means of two different queues: the transmission queue, or XMIT_Q referenced as 100, and the reception queue, or RCV_Q referenced as 102.

ATM Cell Handler at the Mobile Terminal

The ATM cell Handler is further split into two sub-entities: one dealing with reception of ATM cells from the interface 62, the other dealing with transmission of ATM cells to the interface 62. The reception side is responsible for building the so-called cell trains on the base of the successive ATM cells received from interface 62. A similar memory management scheme as the one used in the Access Point may be used in the Mobile Terminal, but others schemes may be adapted without departing from the scope of the invention. The available memory (within data storage 70) is organised as a pool of buffers, each buffer being dimensioned to contain a train made of Ntrain ATM cells. At any point in time, several such buffers are available, each of them corresponding to a given traffic type, as identified in Table 3 (with even index). The selection of the right buffer to use may on a preferred embodiment of the invention rely on the same approach as the one used in the Access Point (for instance using a leaky buffer based method). On another embodiment, the selection of the rigth buffer can also take advantage of the information contained in the FH control packet to determine the part of the traffic which remains below the RBW threshold. If the buffer is found full (meaning that the received ATM cell is the last one of the cell train), then a new buffer must be dynamically allocated to host other ATM cells to come later. As each buffer is associated to a unique traffic type, it means that the XMIT_Q queue is implicitly instanced by traffic types. It can thus be seen as a set of different sub-queues MPDU_Qj, each of them being characterised by its own priority index j (even), as specified in Table 3.

The transmission side of the ATM Cell Handler is responsible for transmitting to the interface 62 the different ATM

cells which have been previously received within MPDU from the interface 60. When an ATM cell has been passed to the interface 62, the corresponding memory can be returned to a pull of free memory.

MPDU Handler at the Mobile Terminal

The MPDU Handler is further split into two sub-entities: one dealing with reception of MPDU from the interface 60, the other dealing with transmission of MPDU to the interface 60.

The transmission side is responsible for sending to the interface 60 the MPDU specified in the slot map (passed from the Slave Scheduler 98) during the UP_RESERVED period, as well as MPDU issued during the UP_CONTENTION period. For this last case, the MPDU Handler is responsible for following the slotted Aloha scheme to be used during the UP_CONTENTION period. Once a MPDU transmission is complete, the associated buffer can be released and returned to a pool of free buffers. In addition, the transmission side of the MPDU Handler must send the bandwidth reservation requests which have been previously issued by the Slave Scheduler 98. Such requests can either take the form of piggybacked information carried by any MPDU flowing from the Mobile Terminal to the Access Point, or take the form of a dedicated control MPDU which is only issued for this purpose. In this later case, the request is sent during the UP_CONTENTION period. It should be noted that the Mobile Terminal can issue during the UP_CONTENTION period a MPDU carrying a bearer information ATM cell which itself carries a piggybacked bandwidth reservation request for remaining traffic to be sent.

The reception side of the MDPU Handler at the Mobile Terminal is responsible for receiving from the interface 60 the MPDU specified in the slot map built by the Master Scheduler 84 during the DOWN period. For each received MPDU, the reception side has several tasks to perform. First it must extract the ATM cells from the MPDU and enqueue them in the RCV_Q queue. Second it must identify the FH control packet received at the beginning of each time frame and pass it to the Slave Scheduler.

Slave Scheduler

The process run by the Slave Scheduler differs from the one of the Master Scheduler as the Slave Scheduler must strictly follow, for the downlink traffic, the slot map built by the Master Scheduler, and is responsible to schedule the part of the uplink traffic which fits within the time slots allocated for it by the Master Scheduler and also to place reservation requests for the part of the uplink traffic which is not covered by the reserved traffic scheduled by the Master Scheduler.

In other words, the Slave Scheduler updates the slot map found in the FH control packet so that the MPDU Handler determines exactly when traffic must be either received or transmitted. As the slot map is a descriptor of the sequence of time slots along the full time frame, it can be split into three different pieces: the slot_mapDOWN, the slot_mapUP_RESERVED and the slot_mapUP_ CONTENTION. The Slave Scheduler keeps the slot_mapDOWN unchanged, while it must specify which part of its uplink traffic will flow either during the reserved time slots of the UP_RESERVED period (by modifying the slot mapUP_RESERVED), or during some time slots of the UP_CONTENTION period (by modifying the slot mapUP_CONTENTION).

The Slave Scheduler processing is represented by FIG. 7. At the very beginning, the Slave Scheduler initialises the static variable nRF (block 122). Then it enters an endless loop which starts each time a new time frame begins (block 124) with the reception (from the MPDU Handler 96) of the FH control packet. The first action is to extract the slot map from FH, to split it into the three slot map sub-fields (DOWN, UP_RESERVED, UP_CONTENTION) and then to evaluate the number SUP_RESERVED of allocated time slots in the UP_RESERVED period (block 126). Then the Slave Scheduler evaluates its pending uplink traffic by compiling the content of the MPDU_Qj queues (j taking even values): it derives the variables ci,j (as previously defined for the Master Scheduler), and the aggregate number of pending uplink traffic ATM cells, noted cPENDING (block 128). Then the Slave Scheduler initialises a variable n to prepare the traffic allocation within the time slots reserved by the Master Scheduler for the UP_RESERVED period (block 130). The next action consists in filling all the reserved time slots with the pending uplink traffic, according to the various priorities identified by the indexes i of the XMIT_Qi queues (block 132). The MPDUs of highest priority are served first, and the Slave Scheduler updates accordingly the slot_mapUP_RESERVED and the number of remaining pending uplink traffic ATM cells cPENDING. When this task has been done, the Slave Scheduler must work for the left uplink traffic, if any. The first point to look at is the presence of any remaining traffic that is close to its time expiry limit (block 134). It means that this traffic cannot wait for the next time frame before reaching its time expiration. If such traffic still remains unscheduled (branch YES of block 134) it has to be issued as soon as possible, that is during the UP_CONTENTION period of the current time frame. Thus the Slave Scheduler updates the slot_mapUP_CONTENTION and the variable cPENDING accordingly (block 136). At that point, the last action to perform is to place reservation requests if any pending traffic is still left unscheduled during the current time frame. This condition is determined by looking at the value of the cPENDING variable (block 138). If all the traffic has already been

scheduled, (branch YES of block 138), then the process goes directly to the very last step (block 148) described later. Otherwise, the Slave Scheduler builds the various reservation requests needed for the remaining traffic (block 140). These requests specify the number of remaining ATM cells per ATM connections, so that the Master Scheduler can later prioritize them according to the corresponding traffic types. Then the Slave Scheduler must determine how to send the reservation requests to the Access Point (more accurately to the Master Scheduler). If some reserved uplink traffic is scheduled during the current time frame (SUP_RESERVED is not null, branch NO of block 142), then the reservation requests must be carried as information piggybacked in the MPDU to be sent during the UP_RESERVED period. For this purpose the Slave Scheduler passes the requests to the MPDU Handler (block 146) so that it can add it to the appropriate uplink MPDU(s). If none reserved traffic flows upward during the current time frame, the Mobile Terminal can only issue a dedicated control MPDU during the UP_CONTENTION period (block 144). For this purpose, the Slave Scheduler builds the control MPDU and allocates it for the UP_CONTENTION period; therefore the slot_mapUP CONTENTION is also updated. The final step is to pass to the MPDU Handler the updated slot map (block 148), so that the MPDU Handler can determine for each period which traffic must be either received or sent.

Claims

1. In a data communication system of the type comprising:

   at least one first network based on a first technology and including at least one first station,
   at least one second network based on a second technology being different than the first technology, and including at least one second station,
   access means for providing communication between the at least first and second stations,

   said system being characterized in that said access means comprise:

   - means for defining a plurality of successive time frames during which traffic of data from said first or second network is carried out, and
   - means responsive to network parameters of each said first and second networks, and to traffic characteristics and constraints, for scheduling the exchange of data information during each said successive time frames.

2. The system of claim 1 further comprising means for varying the duration of said successive time frames as a function of the traffic load of the system.

3. The system of claim 1 or 2 wherein said means for varying the duration of said successive time frames comprise means for insuring that said time frame duration remains below an upper bound to comply with latency constraints imposed by the technology based traffic.

4. The system of claim 1, 2 or 3 wherein said means limiting the duration of said successive time frames are invoked at each time frame.

5. The system of anyone of claims 1 to 4, wherein said successive time frames are divided into three periods, the first period for contention free transmission from said first network to said second network; the second period for contention free transmission from said second network to said first network; and the third period for contention based transmission from said second network to said first network.

6. The system of claim 5, further comprising means for varying the duration of each said three periods as a function of the traffic load and of the traffic nature of the system.

7. The system of claim 6, further comprising means for insuring that the third period has not null minimum duration, and wherein said means for insuring are invoked at each said time frame.

8. The system of claim 7, wherein said means for computing the minimum duration of said third period are based on the number of stations of said second network without scheduled uplink traffic during said second period.

9. The system of claim 7 or 8, wherein said means for computing the minimum duration of said third period are a growing linear and/or exponential function of the number of stations of said second network without scheduled traffic during said second period.

10. The system of anyone of claims 1 to 9, wherein said first network is an ATM network (32), said second network is a wireless network comprising a plurality of Mobile Terminals (10,12,14,16), each Mobile Terminal including a transceiver (46) and wherein said access means comprise an Access Point (18,20) having a transceiver (38) for radio communication with the transceivers of each of the plurality of Mobile Terminals.

11. The system of claim 10, wherein said means limiting the duration of said successive time frames utilise parameters (PCR, CDVT, CTD, BT) corresponding to each ATM connection making the ATM traffic.

12. The system of claim 10 or 11, wherein each of said three periods is divided into a plurality of time slots, each of them lasting the time required for the transmission of an ATM cell.

13. The system of claims 10, 11 or 12, wherein several ATM cells can be transmitted either by the Access Point or by said plurality of Mobile Terminals, during a sequence of contiguous time slots, forming a cell train.

14. The system of anyone of claims 10 to 13, wherein said Access Point or said plurality of Mobile Terminals further comprising means for storing the ATM cells to be transmitted in memory buffers having the structure of a said cell train.

15. The system of anyone of claims 10 to 14, further including means for ensuring that the part of said ATM traffic which has been guaranteed by an ATM connection contract established at an ATM connection set-up, is carried over a wireless channel between said Access Point and said plurality of Mobile Terminals using a reservation based, contention free access method.

16. The system of claim 15, wherein said means include both static and dynamic reservation means.

17. The system of claim 15 or 16, comprising means to define a set of priorities for said ATM traffic, which governs which type of static or dynamic reservation means apply for this traffic.

18. The system of claim 17, wherein said means defining the set of ATM traffic priorities depend on the service class and quality of service parameters corresponding to each of ATM connections making said ATM traffic.

19. The system of claim 17 or 18, wherein said means defining the set of ATM traffic priorities define two traffic thresholds derived from the PCR, SCR and MCR parameters of the various ATM connections making said ATM traffic.

20. The system of anyone of claims 1 to 19, wherein said plurality of Mobile Terminals further comprising means for scheduling said ATM traffic during said time frame, conjointly within said Access Point.

21. The system of claim 20 wherein the scheduling means of said plurality of Mobile Terminals further comprising means to issue, during said time frame, reservation requests for transmission to said Access Point of the portion of the traffic not scheduled by said Access Point during the current said time frame.

22. The system of claim 21, wherein the reservation requests can either be carried as piggybacked information within scheduled traffic sent to the said Access Point, or be carried as a dedicated unscheduled control packet sent to said Access Point.

23. The system of anyone of claims 20 to 22, wherein the scheduling means of said plurality of Mobile Terminals comprise means to schedule transmission of ready to be sent ATM cells within the sub-set of said second period which has been allocated to it by the scheduling means of said Access Point.

24. The system of anyone of claims 20 to 23, wherein the scheduling means of said plurality of Mobile Terminals comprise means to schedule transmission of ready to be sent ATM cells during said third period, if said ready to be sent ATM cells cannot wait the next time frame before being transmitted to said Access Point.

25. The system of anyone of claims 10 to 24, wherein the scheduling means of said Access Point broadcast to said plurality of Mobile Terminals at the beginning of each time frame, a frame header control packet specifying the structure and the content of said time frame.

26. The system of claim 25 further comprising a descriptor specifying the traffic to be scheduled for each time slot.

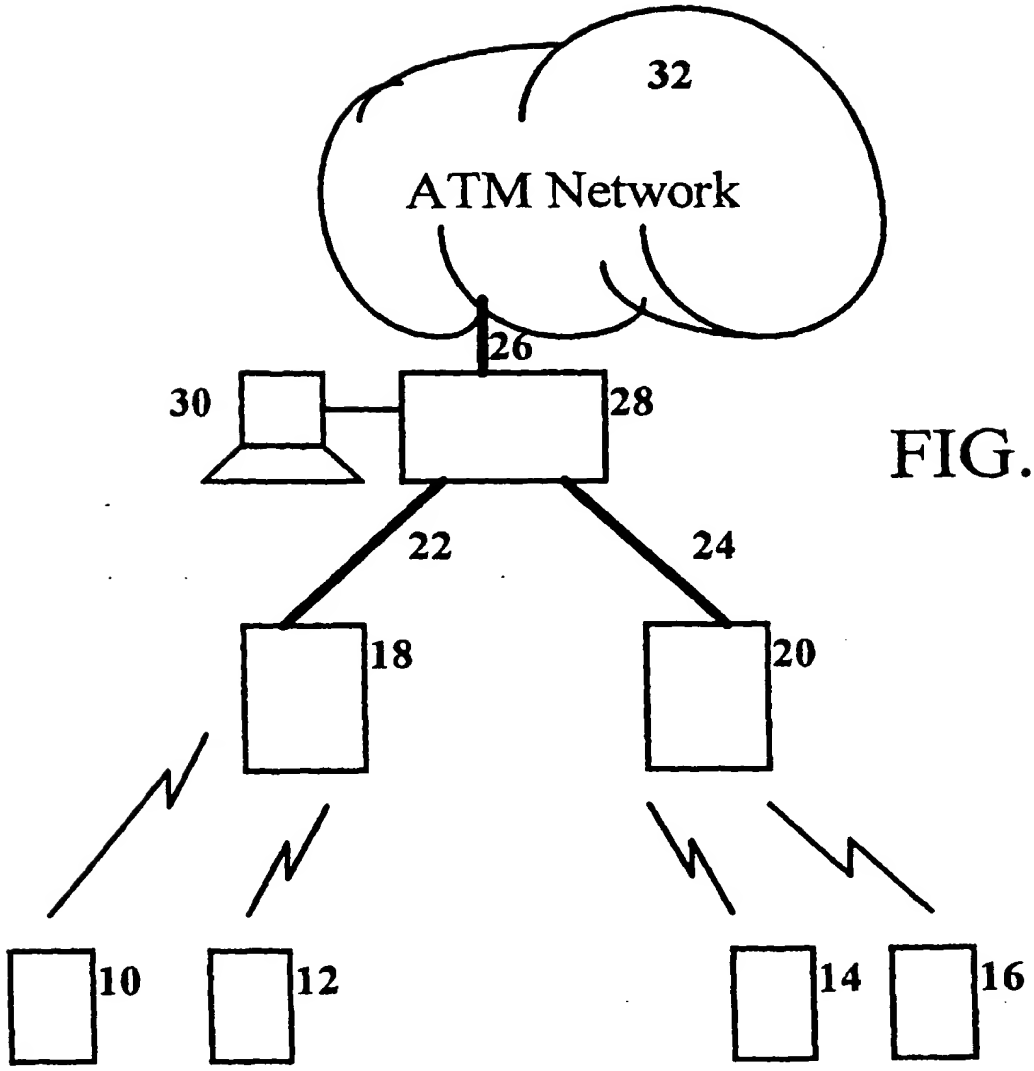


FIG. 1.

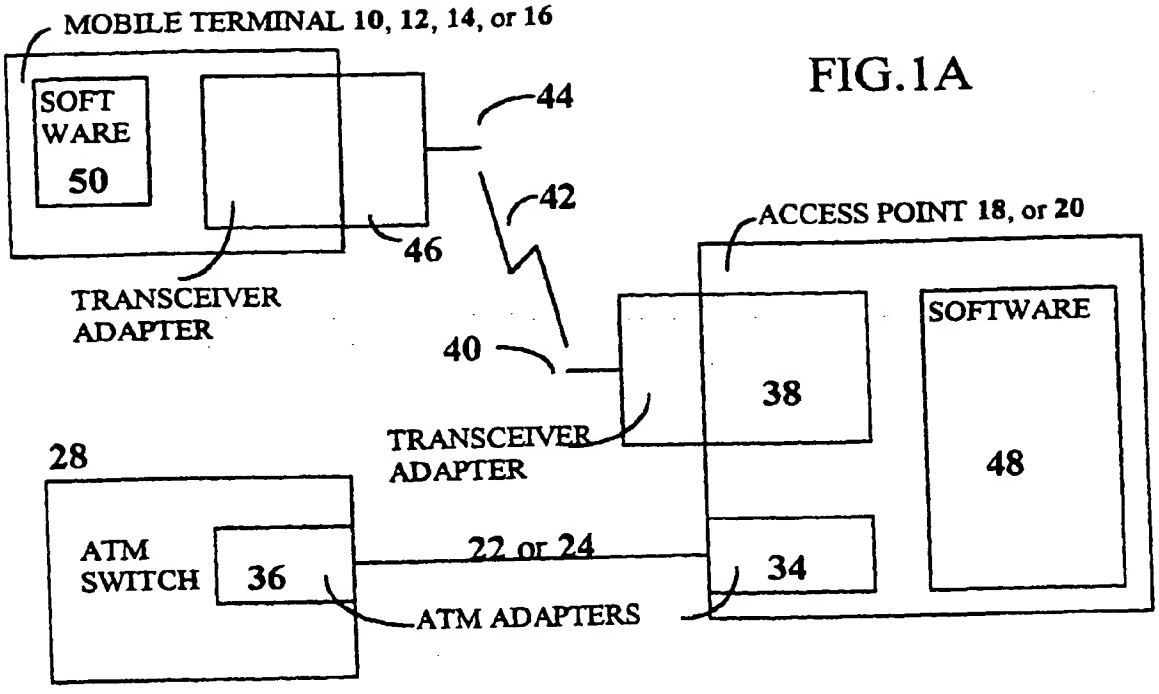

MOBILE TERMINAL 10, 12, 14, or 16
SOFT WARE
50
44
42
46
TRANSCEIVER ADAPTER
ACCESS POINT 18, or 20
40
38
SOFTWARE
48
TRANSCEIVER ADAPTER
28
ATM SWITCH
36
22 or 24
34
ATM ADAPTERS

FIG.1A

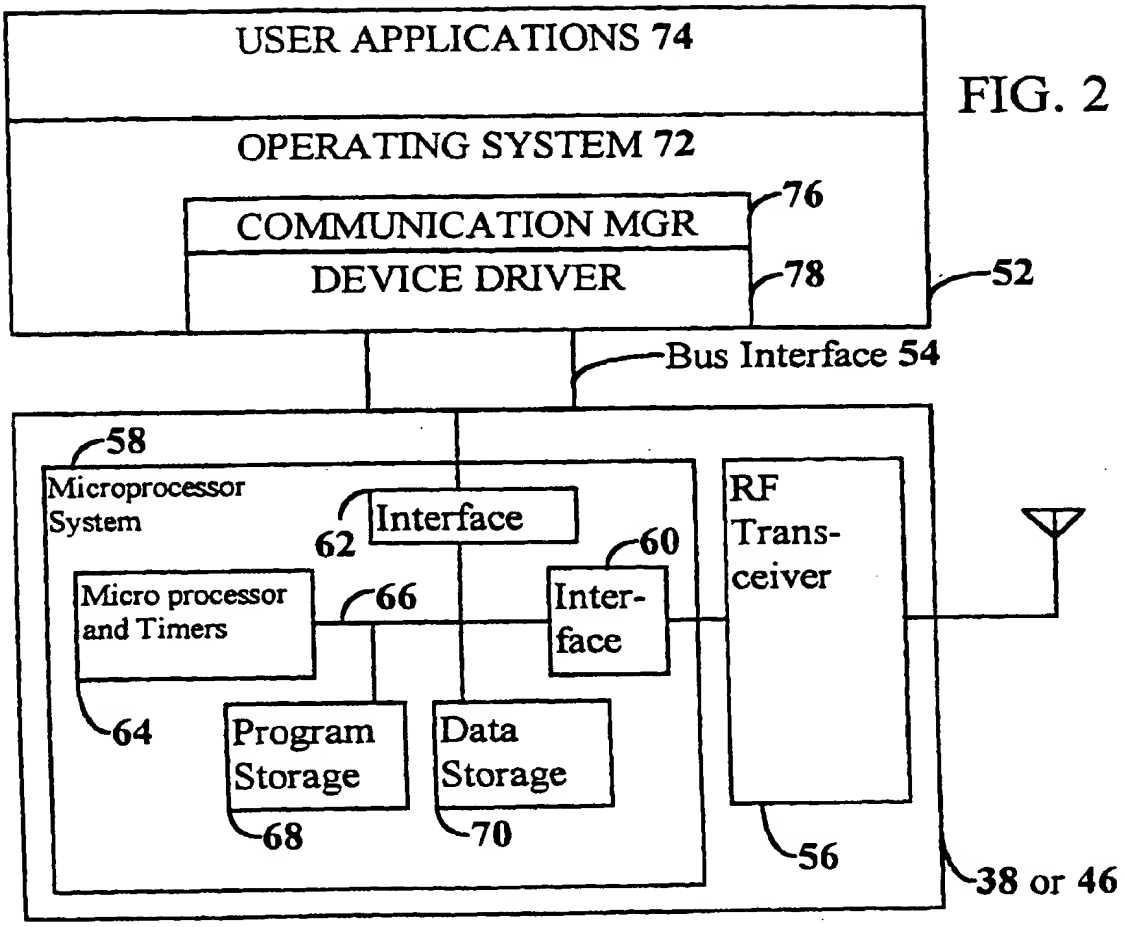
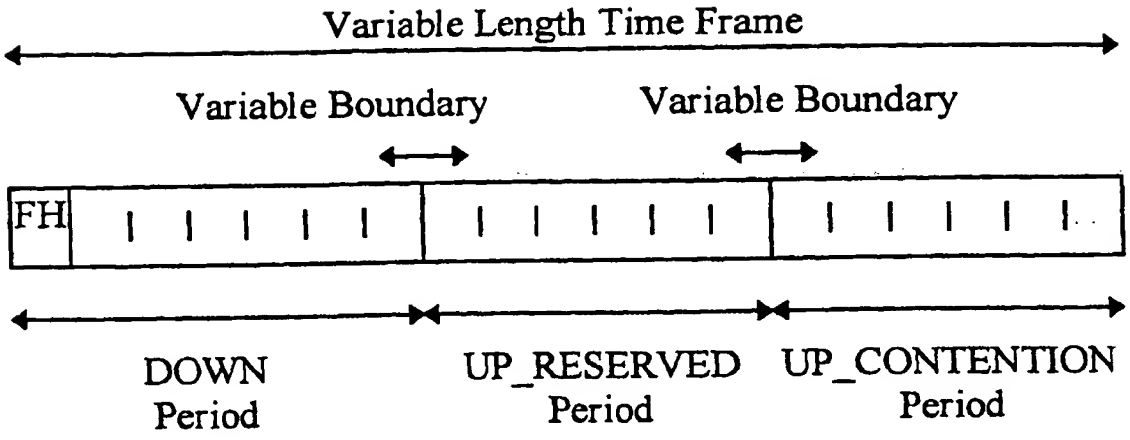

USER APPLICATIONS 74
OPERATING SYSTEM 72
COMMUNICATION MGR
DEVICE DRIVER
76
78
52
Bus Interface 54
58
Microprocessor System
62
Interface
60
Micro processor and Timers
66
Inter-face
RF Trans-ceiver
64
Program Storage
68
Data Storage
70
56
38 or 46

FIG. 2

FIG. 3


Variable Length Time Frame
Variable Boundary
Variable Boundary
FH
DOWN Period
UP_RESERVED Period
UP_CONTENTION Period

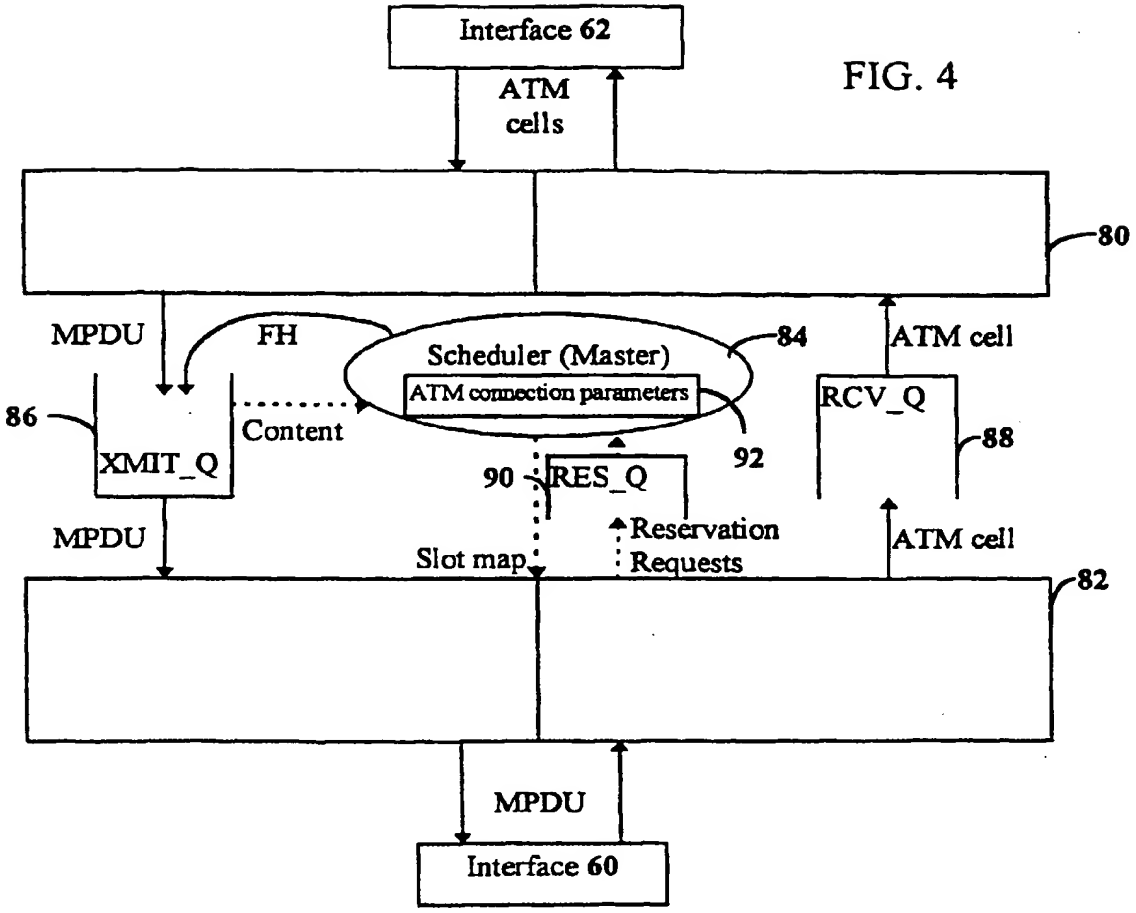
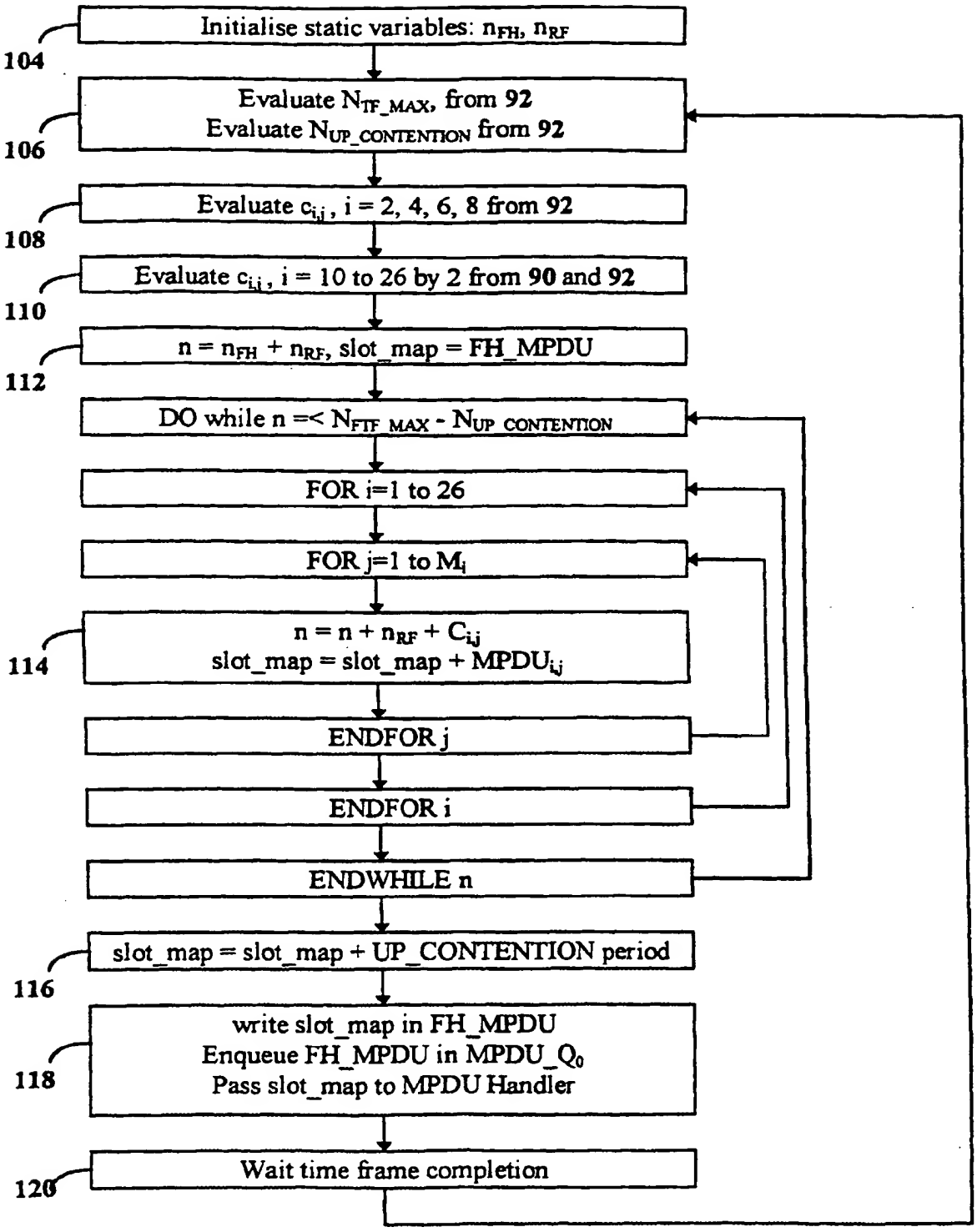

Interface 62
ATM cells
80
MPDU
FH
Scheduler (Master)
84
ATM cell
ATM connection parameters
RCV_Q
86
Content
XMIT_Q
92
88
90
RES_Q
MPDU
Reservation Requests
ATM cell
Slot map
82
MPDU
Interface 60

FIG. 4

FIG. 5


Initialise static variables: n_{FH}, n_{RF}
104
Evaluate N_{TF_MAX}, from 92
Evaluate $N_{UP_CONTENTION}$ from 92
106
Evaluate $c_{i,j}$, i = 2, 4, 6, 8 from 92
108
Evaluate $c_{i,j}$, i = 10 to 26 by 2 from 90 and 92
110
$n = n_{FH} + n_{RF}$, slot_map = FH_MPDU
112
DO while $n =< N_{FTF_MAX} - N_{UP_CONTENTION}$
FOR i=1 to 26
FOR j=1 to M_i
$n = n + n_{RF} + C_{i,j}$
slot_map = slot_map + $MPDU_{i,j}$
114
ENDFOR j
ENDFOR i
ENDWHILE n
slot_map = slot_map + UP_CONTENTION period
116
write slot_map in FH_MPDU
Enqueue FH_MPDU in $MPDU_Q_0$
Pass slot_map to MPDU Handler
118
Wait time frame completion
120

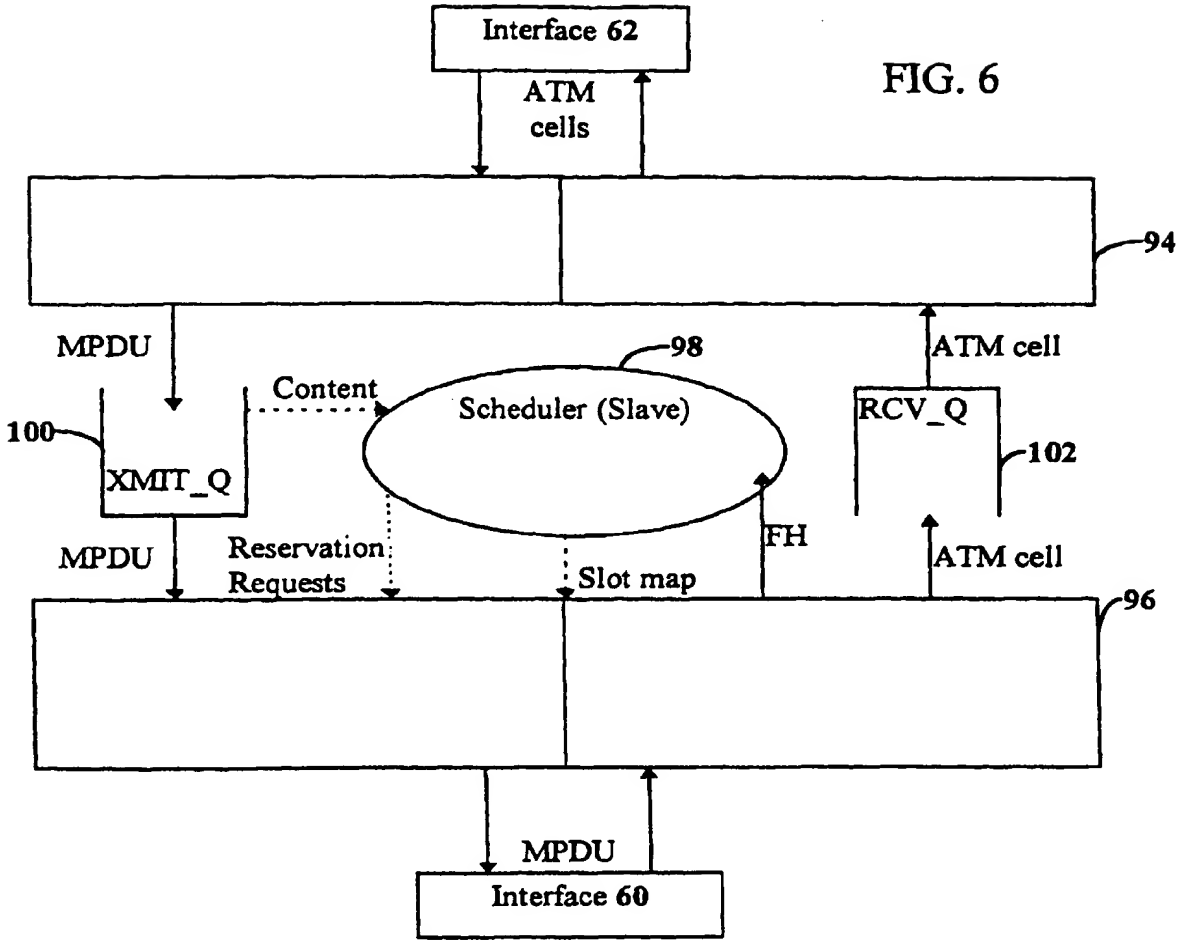
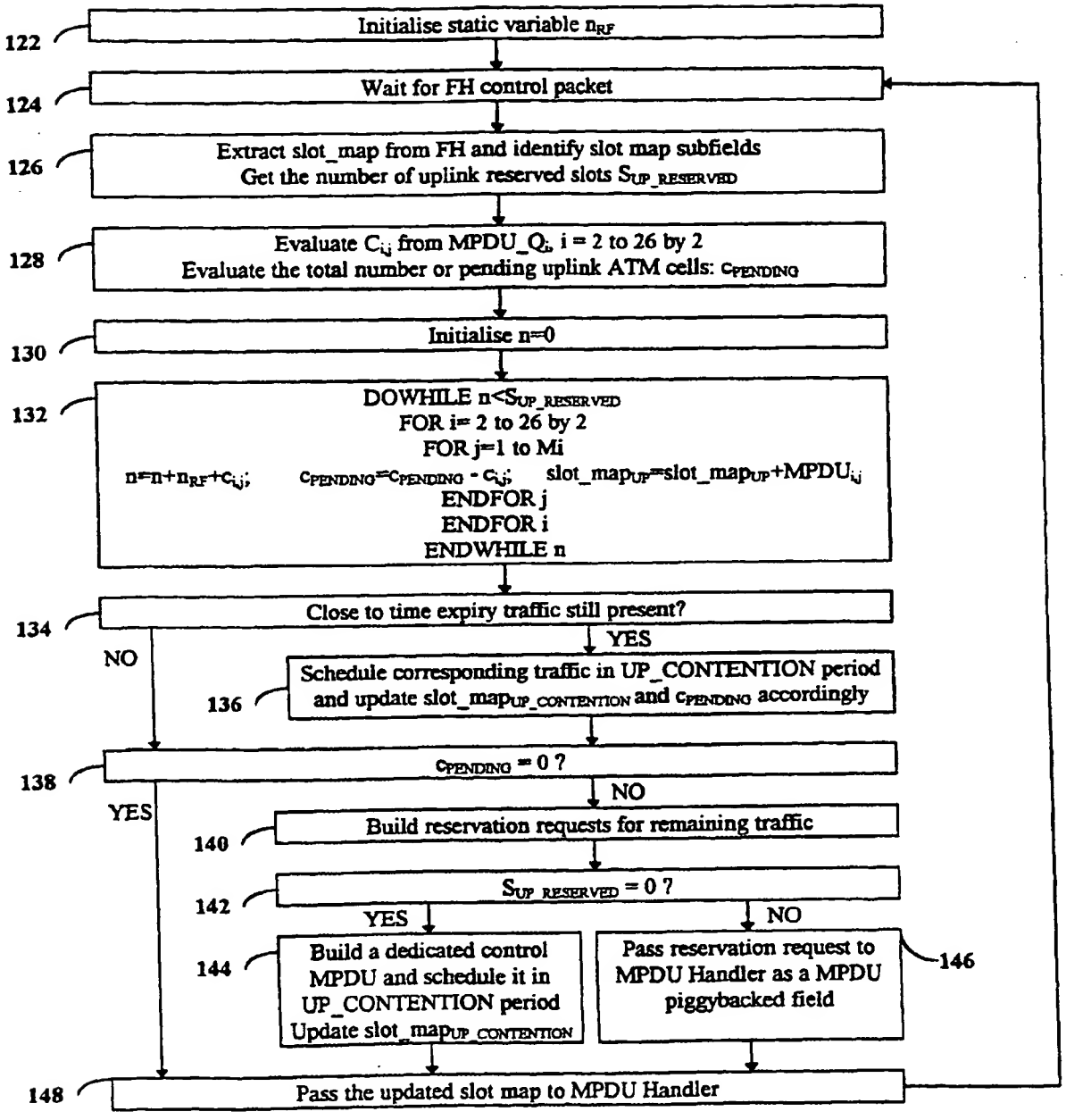

Interface 62
ATM cells
94
MPDU
98
ATM cell
Content
Scheduler (Slave)
RCV_Q
100
XMIT_Q
102
MPDU
Reservation Requests
Slot map
FH
ATM cell
96
MPDU
Interface 60

FIG. 6

FIG. 7


122
Initialise static variable n_{RF}
124
Wait for FH control packet
126
Extract slot_map from FH and identify slot map subfields
Get the number of uplink reserved slots $S_{UP_RESERVED}$
128
Evaluate $C_{i,j}$ from MPDU_$Q_{i,j}$, i = 2 to 26 by 2
Evaluate the total number or pending uplink ATM cells: $c_{PENDING}$
130
Initialise n=0
132
DOWHILE $n<S_{UP_RESERVED}$
FOR i= 2 to 26 by 2
FOR j=1 to Mi
$n=n+n_{RF}+c_{i,j}$; $c_{PENDING}=c_{PENDING}-c_{i,j}$; $slot_map_{UP}=slot_map_{UP}+MPDU_{i,j}$
ENDFOR j
ENDFOR i
ENDWHILE n
134
Close to time expiry traffic still present?
YES
NO
136
Schedule corresponding traffic in UP_CONTENTION period and update $slot_map_{UP_CONTENTION}$ and $c_{PENDING}$ accordingly
138
$c_{PENDING}$ = 0 ?
YES
NO
140
Build reservation requests for remaining traffic
142
$S_{UP_RESERVED}$ = 0 ?
YES
NO
144
Build a dedicated control MPDU and schedule it in UP_CONTENTION period
Update $slot_map_{UP_CONTENTION}$
146
Pass reservation request to MPDU Handler as a MPDU piggybacked field
148
Pass the updated slot map to MPDU Handler

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(11) EP 0 804 006 A3

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(71) Applicant: **International Business Machines Corporation**
Armonk, N.Y. 10504 (US)

(72) Inventor: **Bauchot, Frédéric**
06640 Saint Jeannet (FR)

(74) Representative: **Schuffenecker, Thierry**
Compagnie IBM France,
Département de Propriété Intellectuelle
06610 La Gaude (FR)

(54) Medium access control scheme for a wireless access to an ATM network

(57) According to the present invention, an adaptive and efficient MAC protocol for wireless access to an ATM network (32) is capable of supporting any type of ATM service class with associated Quality of Services parameters. An ATM cell-switched architecture is utilised in which several ATM Mobile Terminals (10,12,14,16) within a given geographic cell (small cells covering a range of several tens of meters) communicate with an ATM Access Point (18,20) using radio frequency channels, which is connected to an infrastructure ATM network by the means of conventional ATM links. Mobile Terminals can operate both indoor and outdoor with limited range and have wireless access to the Access Points on the ATM network.

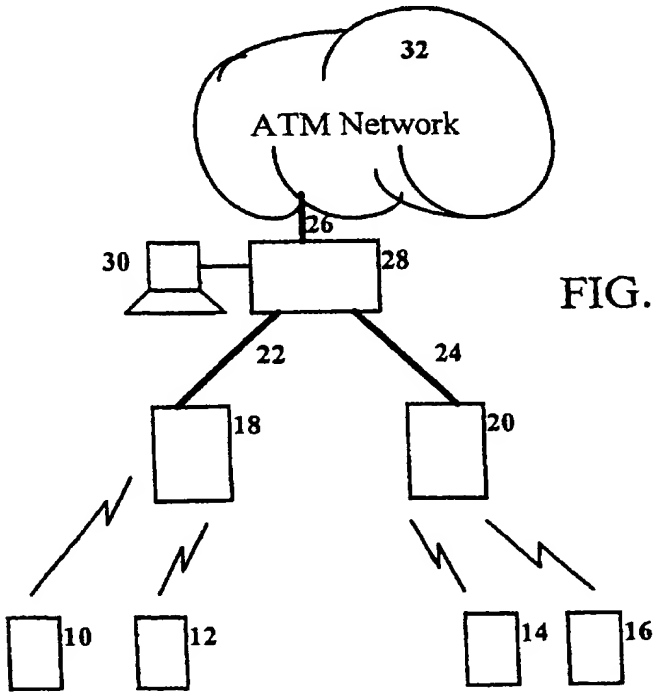

FIG. 1.

EP 0 804 006 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 97 48 0017

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 5 384 777 A (AHMADI ET AL.) * column 1, line 31 - line 65 * * column 2, line 4 - line 57 * * column 3, line 24 - line 68 * * column 5, line 38 - column 7, line 53 * * column 8, line 20 - line 30 * * figure 3 * ---	1-9	H04L12/28
X	US 5 123 029 A (BANTZ ET AL.) * column 1, line 16 - column 3, line 35 * * column 5, line 44 - column 7, line 50 * * column 8, line 17 - line 62 * * figures 3,3A * -----	1-9	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 August 1997	Vaskimo, K

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid,

namely claims:

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions,
namely:

See sheet B.

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid,

namely claims:

☒ None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims,

namely claims: 1-9

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B
EP 97480017.9

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims 1-9: A data communication system with two networks based on different technologies, each network including at least one station; access means comprising means for defining time frames and scheduling traffic; the system further comprising means for varying the duration of time frames as a function of the load of the system.

2. Claims 1, 10-26: A data communication system with two networks based on different technologies, each network including at least one station; access means comprising means for defining time frames and scheduling traffic; wherein operation of the system is optimized for the case where first network is an ATM network and the second network is a wireless network.